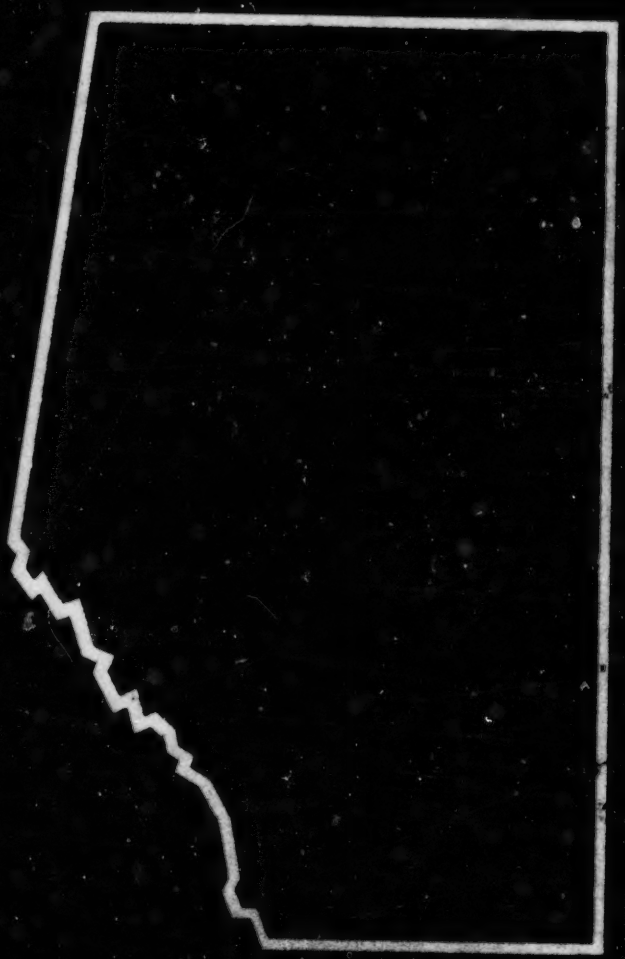
# REMOTE SENSING

## For Forest Resources



Alberta

REMOTE SENSING

FOR FOREST RESOURCES

# An Evaluation of Medium-small Scale Natural Color and Color Infrared Photography and Medium Scale Black and White Infrared for the Identification of Selected Forest Resource Features

by

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## DEMONSTRATION PROJECT

This is the abridged edition of a remote sensing demonstration project report sponsored by the Alberta Remote Sensing Center, Alberta Environment. The complete report is available for in-Center study.

## COVER PHOTOGRAPH

Black and White infrared 1:15,000 photograph, Cache Percotte Forest, Hinton, Alberta

# A B S T R A C T

The project evaluated the suitability of 1:15,000 scale black and white infrared and three scales (1:30,000, 1:50,000, 1:70,000) of natural color and color infrared photography for the identification of selected resource characteristics and qualities.

Resource features related to forestry, recreation and wildlife habitat were interpreted by a large number of participants having varying levels of experience and color perception. Test areas were chosen to represent the Boreal, transition/foothills and subalpine forest regions in Alberta. The accuracy of identification and time required for interpretation were evaluated with respect to film type, scale, interpreter photo-interpretation and forest inventory experience and color discrimination ability. Imagery acquisition costs were evaluated.

Identification accuracy of most resource features on natural color and color infrared at scales of 1:30,000, 1:50,000 and 1:70,000 was at least equivalent to that on 1:15,000 black and white infrared. Inventory experience, photo-interpretation experience and color perception ability did not seriously affect the accuracy of identifying any of the features examined. Interpreters preferred either conventional black and white infrared or color infrared at 1:30,000 demonstrating that personal preference may not be a reliable indicator of imagery suitability for interpretation.

Wider use of medium-small scale color photography for inventory may be justified by the identification accuracy attained, and the appreciable reduction in imagery acquisition cost when compared with the medium scale black and white infrared photography.

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## Introduction

Increasing emphasis is being placed on multiple resource use. To accommodate this, inventory efforts between resource disciplines must be coordinated. Inventory design should enable efficient collection of the required data using new cost-effective techniques (Sayn-Wittgenstein 1980). Currently in Alberta, 1:15,000 black and white infrared is interpreted for forest cover, detail from which is transferred to base maps. Due to the availability of this photography and the high costs incurred in the acquisition of alternative imagery, other resource analysts have accepted this for their own purposes. However it is questionable whether a single film and scale best serves a range of resource disciplines (Fraser 1980).

The choice of film type and scale for aerial photo-interpretation of forest stands, potential recreation areas and wildlife habitat requires a critical assessment of suitability for each resource characteristic. The objective of this project was to evaluate the use of natural color and color infrared aerial photography at scales of 1:30,000, 1:50,000, and 1:70,000 for the identification of selected forest resource features as possible alternatives to the 1:15,000 scale black and white infrared photography currently used in Alberta by:

1. Evaluating the effects of film type and scale on the accuracy of photo-interpretation by experienced foresters, recreation inventory personnel and wildlife habitat biologists.
2. Examining the cost effectiveness of this imagery for the identification of selected forest characteristics and qualities.

The problem was to determine the relationships between accuracy, cost, film type, scale and interpreter experience for the identification of selected resource characteristics.

The scope of the study was limited to three major forested regions in the province of Alberta. Specifications for the identification of forest stands, potential recreation sites and wildlife habitat sites were based on operational inventory procedures of the Alberta Forest Service, the Wildlife Habitat Section and Alberta Provincial Parks.

## Imagery Selection

As alternatives to black and white infrared photography (Kodak 2424) this study considered natural color (Kodak Aerocolor 2445) and color infrared (Kodak Aerochrome 2443) films. Both films take advantage of the increased information provided by hue, value and chroma, attributes which become particularly important with a reduction in scale (Sayn-Wittgenstein 1978). Natural color, sensitive to visible light, provides reproductions similar to the original scene which allows inexperienced interpreters to quickly become accustomed to it (Cooper and Smith 1966). Color negative, rather than positive reversal film, was taken due to its high resolution, its exposure latitude and its flexibility. Color infrared was selected due to recent studies attesting to its advantages for vegetation analysis (Fritz 1967), species identification (Jaques 1976) and stand delineation (Cox, Baxter and Weber 1975). The penetration of haze by color infrared, especially at high altitudes, is well documented (Heller 1971, Sayn-Wittgenstein 1978).

Foresters generally prefer scales of 1:24,000 or larger (Marshall and Meyer 1978). Small scale photography has been recommended for reconnaissance work, but it has been suggested that sufficient detail may also exist on small scale imagery for the description of more detailed forest stand conditions (Nielsen and Wightman 1971). Current operational work and advantages of greater synoptic view and reduction in handling costs (Dempster and Scott 1979) justified the selection of a range of commercially available scales for this study. The smallest scale (1:70,000) was selected based on the operational ceiling of the Canada Center for Remote Sensing aircraft equipped with a Wild RC-10 camera (15.2 cm lens). The largest scale (1:30,000) was judged to be the limit at which the increased cost of color imagery was justified. The 1:50,000 provided a suitable intermediate value between the two.

## Interpreters

There are numerous human factors which may affect photo-interpretation including stereoscopic perception, visual acuity, imagination, patience, motivation and regional knowledge. Of particular interest was the relationship between experience and accuracy. Photo-interpretation experience may have no effect while practical field experience may be more important (Draeger and Carneggie 1974). In addition, color discrimination was considered as possibly significant due to the large number of people in the population experiencing poor color perception (Padgham and Saunders 1975). All interpreters who participated in this study had some prior experience with aerial photographs and a working knowledge of the provincial inventory system. Of the three "human" factors investigated, three classes were recognized within each. Experience levels for both field and photo-interpretation had ranges of less than 6 months, 6-24 months and more than 24 months. The total color discrimination error scores obtained from the Farnsworth-Munsell color test were also broken down into three groups: 0-39 (good), 40-68 (moderate), 69 plus (poor).

## Costs

The selection of suitable imagery for photo-interpretation is a function of suitability for interpretation, interpretation time, material and cost of imagery flights. Increased accuracy in

stratification and feature identification reduces the amount of field work required for verification, which may offset any increased cost incurred with the acquisition of more expensive imagery. Interpretation cost is also associated, to a lesser degree, with the actual time spent identifying a site. This factor was examined through a time study conducted during interpretation sessions.

The costs of acquiring the imagery were compared.

## Methods

A controlled experiment was conducted to evaluate photo-interpretation accuracy on various film/scale combinations for test areas representing three major forest regions in Alberta.

Accuracy was based on the comparison of interpretation results with evaluations from field measurements for each of the sample areas.

A controlled four factor experiment was used to test the effects of each factor on interpretation accuracy for the color films. Factors included region, film type, scale and interpreter group as follows:

1. Region: Boreal, Foothills, Subalpine regions.
2. Film: 2 levels (natural color and color infrared)
3. Scale: 3 levels (1:30,000, 1:50,000, 1:70,000)
4. Interpreter Group: 3 levels (good medium fair) based on:
   a. field inventory experience in the discipline,
   b. general photo interpretation experience,
   c. color discrimination ability.

To test for differences in accuracy or time of interpretation between the six color combinations and 1:15,000 black and white infrared, each combination was taken as a treatment in a randomized block experiment and analyzed with the "Quade" nonparametrics test (Conover 1980).

## Resource Characteristics and Qualities

Selection of the resource characteristics and qualities to be identified by the interpreters was based on a literature review, consultations with resource analysts from Alberta Energy and Natural Resources and an evaluation of current inventory specifications. Resource characteristics were limited to those features of importance for management planning in forestry, wildlife and recreation applications which could reasonably be interpreted.

## Forestry

Interpretation of stand conditions followed specifications of the Alberta Forest Service Phase III inventory. According to these interpretation procedures, forest land is stratified into non-productive land (water, muskeg, scrub, barren) and productive forest (land capable of producing at least 50 plus cubic metres per hectare gross roundwood volume of all species at 120 years). Stocked productive forest land (areas with greater than six percent commercial species crown cover) is further described by crown density class, height class, species composition, commercialism, age (origin) and relative site index. The stand classification system provides for descriptions using up to four different species listed in decreasing order of gross roundwood volumes or crown cover. For analysis, interpreter observations of species composition were grouped into one of eight major classes determined to be important for timber management planning. Additional evaluations of understory species composition, slope and disturbance were not included in this study. Stand identification was based on the specifications given in Table 1.

## Wildlife

Biologists require data on the arrangement and dispersal of food, water and shelter. Specifically, habitat analysis requires information on the height and species composition, types of water resources and wetlands, and the cover and regeneration conditions of logged and burned forest areas. Specifications for the wildlife habitat interpretation included habitat type, species, vegetation height, slope, aspect, and site condition (Table 2). The photo-interpretation code sheet was compiled by Ms. Beth McCallum of the Wildlife Habitat Section, Department of Energy and Natural Resources.

## Recreation

Recreational opportunities depend on the variety and distribution of landforms and vegetation cover on a site. Essential considerations in site selection for further development are:

1. Accessibility.
2. Availability of water.
3. Suitability of the terrain.

A recreation inventory manual, compiled by the Resource Assessment and Management Section, Outdoor Recreation Planning Branch, Alberta Provincial Parks (prepared by G. More and S. Loomis) provided the criteria and classification for interpretation. Completed site inventories indicate "... prime potential sites for candidate review for development". The most important variables were extracted from these specifications, describing the biophysical and water body characteristics of the site. For comparative purposes, two subjective estimates of site attractiveness and suitability for camping were included.

## Test Sites and Aerial Photography Acquisition

Three test sites (Figure 1) were selected within the Green Zone of Alberta, representing the major forest regions

(boreal, foothills and subalpine) in the province (Rowe 1972). Characteristic species within the flat to rolling boreal region are white spruce (Picea glauca (Moench) Voss.), black spruce (Picea mariana (Mill.) B.S.P.), trembling aspen (Populus tremuloides Michx.), lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.), and larch (Larix laricina (Du Roi) K.Koch.). Common species within the lower foothills transition zone are lodgepole pine, trembling aspen, balsam poplar (Populus balsamifera L.), white spruce, and black spruce occurring in mixed wood stands over rolling topography. The eastern slopes subalpine area consists of large tracts of conifer stands, namely engelmann spruce (Picea engelmannii Parry), alpine fir (Abies lasiocarpa (Hook.)Nutt.), lodgepole pine, trembling aspen, and black spruce, inhabiting valley outwash.

Figure 1. Study area.

Due to heavy atmospheric haze conditions, caused by forest fires, aerial photography was not flown over the three test sites until September 14, 1979. Although shadow effects were increased by the lower sun angle during September, the imagery was judged to be comparable to that available in midsummer as it was a warm fall and the leaves had not taken on their fall coloration. Actual scales acquired over each test site are summarized in Table 4. The photography was processed to prints for field use and to transparencies for photo-interpretation.

## Measurements

Within each of the three forest regions, two sample locations were independently assigned to each of the seven film/scale combinations. The 42 forest stands were randomly selected from stocked productive forest land. Recreation sites of five to ten hectares were selected on the basis of reasonable vehicle access and proximity to water as specified by More and Loomis (1980). Wildlife habitat sites of five to ten hectares were subjectively located in accessible unstocked productive and unproductive forest areas. All stands or sites were delineated on the photos to ensure identical boundary location for interpretation. Example sites are illustrated on Figures 2-4.

Interpretation sessions were conducted at the Alberta Remote Sensing Center. Prior to the individual sessions, instruction was given on interpreting color films. A set of "training" photos, illustrating typical stand interpretations on various film/scale combinations, was provided for inspection prior to the interpretation session. On arrival at the Center, participants were screened by completing an Ishihara Pseudoisochromatic Color Blindness Test which indicated that no interpreters were conclusively red-green deficient. This was followed by the Farnsworth-Munsell 100 Hue Test* and instruction on the operation of the Interpretscope. Starting with a randomly chosen block, the film/scale combinations were presented to the interpreter in random order. Relevant information regarding film type and scale, geographical location and direction of view was provided. Average stand age was given for the estimation of site index of forest stands.

Interpretation time was recorded, excluding time for instrument instruction, stereo set-up and photo-handling. On completion of the interpretation, the participant completed the 100 Hue Test once more, and filled out a questionnaire indicating personal experience levels and imagery preferences.

"True" forest stand descriptions were based on a summary of field measured stand characteristics (Phase III inventory specifications were used) with the exception of stand density. Stand density values were extracted from unpublished Phase III interpretation maps. With a random start, ten point samples were located systematically along the main axis of each delineated stand. Trees were tallied by

* Pseudoisochromatic charts test the observer's ability to distinguish mixtures of reflected monochromatic wavelengths (Padgham and Saunders, 1975). The Farnsworth-Munsell 100 Hue Test provides a measure of interpreter color discrimination and indicates the location of color confusion zones. The procedure is described in the test manual (Revised 1957 by D. Farnsworth, Munsell Color Company Limited).

species and diameter class. Heights were taken of the four dominant/codominant trees closest to the plot center. One age (stump height) was taken of a sample tree falling within the dominant (by basal area) species group.

Basal area for each species and Lorey's height was calculated from the sample data. Commercialism was calculated from the conversion of basal area to volume as described in the Phase III inventory specifications. Site was estimated using Alberta Forest Service site index curves.

Recreation and wildlife habitat sites were described during field inspections. Experienced personnel assisted to ensure realistic site descriptions. A professional wildlife biologist visited all habitat sites, and a recreation inventory technician inspected six recreation sites to verify the field observations.

## Analysis

Interpretation accuracy was determined by the amount of agreement between the photo observations (from transparencies) and the field measurements. The calculation of percent correct for each interpreter/region/film/scale combination was based on the success or failure to duplicate the accepted description on the 2 test sites.

Thirty-six interpreters (17 forestry, 12 recreation, 7 wildlife) participated and were assigned to one of three groups based on inventory experience, photo-interpretation experience and color discrimination ability. Grouping by experience was based on questionnaire returns which indicated only general inventory and photo-interpretation experience, not specific familiarity with particular areas or the film/scale types being tested here. The color discrimination score was the average total score, over two trials, of the Farnsworth-Munsell 100 Hue Test. Limits on the discrimination groups were defined to provide approximately equal numbers of interpreters within each group for analysis. Table 5 shows the breakdown of number of interpreters within each group.

Analysis and hypothesis tests were based on treating the data as four separate experiments. All analyses were conducted at the 95% significance level.

Tukey (Steel and Torrie 1960) and Scheffe (Scheffe 1959) multiple comparisons were used to test for significant differences between treatment levels of the three factors within each experiment. Mean square error values for the calculation of these contrasts were taken from the analyses of variance.

Cost effectiveness was approached in two ways. First, the times recorded for the identification of two sample sites per stereo pair by film/scale and area combination were analyzed. Analysis procedures, consisting of the four separate experiments, were similar with times recorded for each participant interpreting the film/scale combinations substituted for the percentage correct data. In addition, costs were calculated for the acquisition of the photography tested for complete stereo coverage of a rectangular block with dimensions 30 by 20 statute miles (48 by 32 kilometers). The cost recovery program of the Canada Center for Remote Sensing was used to generate basic flight plan data and cost estimates.

## Results and Discussion

Analysis of identification accuracy is described here by resource characteristic and quality in the following order: forestry, recreation and wildlife. Cost effectiveness is examined by comparing interpretation time and acquisition costs.

Table 6 summarizes the results of the analyses of variance of identification accuracy for color and color infrared films. Statistically significant effects and interactions are indicated by asterisks. Variance ratio values have not been included. Table 7 presents average percent correct for each film and scale combination.

## Forestry

The interpretation of density was more accurate on the 1:70,000 scale (72 percent correct) than the 1:50,000 scale (59 percent correct), averaged over the films and interpreter groups (Table 6). It is commonly assumed that crown closure is overestimated at smaller scales due to the appearance of compression. This was not apparent here, possibly due to the acceptance of the initial Phase III interpretation as ground control, and the higher densities (mainly C and D) encountered in the sample stands. No differences in the accuracy of identification were detected by film type over any interpreter group, nor was it related to inventory experience, photo-interpretation experience or color discrimination ability.

The identification of height class was not affected by film type, photo scale, inventory experience, photo-interpretation experience or color discrimination ability. Stand height is normally estimated through the perception of parallax. However, parallax is difficult to measure with decreasing scales when there is less relief displacement and vertical exaggeration. It seems the interpreters used other visual clues such as texture and shadows, and indirectly species and stand age, to assist them. The accuracy of height estimation was also found different with the interaction of film and scale (Table 6). Notable is the position of color infrared 1:30,000, which was generally better than color infrared 1:50,000 or natural color 1:30,000. This is partially explained by the film types themselves, assuming parallax is not the determining factor in estimating heights. Haze effects are less on the color infrared resulting in greater color contrasts and

sharper detail. At 1:30,000 the low sun angle produced long tree shadows which were enhanced on the color infrared. Consequently, the interpreters could rely on more direct information from the color infrared 1:30,000 than the natural color 1:30,000. Interestingly, natural color was better at a scale of 1:50,000 than 1:30,000. This may be attributed to the lack of contrast at the larger scale, and the advantages of the greater synoptic view for comparisons to the surroundings at 1:50,000.

The identification of species composition was related to scale, averaged over the film types and interpreter experience/ability groups. Accuracy scores on the 1:50,000 scale (53 percent correct) were better than the 1:70,000 scale (40 percent correct). This suggests that there is a scale limit beyond which color information does not compensate for less spatial resolution.

The interaction of film and scale also affected the accuracy of species identification. Color infrared 1:50,000 was better than both color infrared 1:70,000 and color infrared 1:30,000. Shadow effects at the larger scale may have caused confusion while the unfamiliar color rendition and the decreased spatial resolution of the smaller scale may have resulted in poorer performance. Accuracy with natural color 1:30,000 and 1:70,000 was equivalent to the color infrared 1:50,000. The superiority of color infrared over natural color for vegetation identification was not apparent here. Complexity of the forest community, the number of tree species, species mixtures, and the occurrence of minor species within stands affects interpretation accuracy (Jano 1980). Since boreal, transition and subalpine forests in Alberta have a simple stand structure, composed primarily of conifers with limited deciduous occurrence (Hosie 1969), it was likely that the interpreters would make the correct choice of species composition.

Inventory experience had a positive influence on accuracy averaged over all scales, regions and film types with participants having 24 or more months performing better than those with less than six months experience (54 and 41 percent correct respectively). Photo-interpretation experience was a significant factor: scores for participants with more than 6 months experience (Group 2: 56 percent correct, Group 3: 50 percent correct) tended to be higher than those with less than 6 months experience (Group 1-44 percent correct). Both experiments suggest the need for training of interpreters in both general inventory work and in photo-interpretation procedures. The accuracy of species recognition was higher for interpreters with moderate color errors (Group 2:52 percent correct) than for those with high error scores (Group 3:38 percent correct), but not significantly higher than those with low color error scores (Group 1:49 percent correct). The cause of these results might be the arbitrary selection of the color discrimination group classes or the possibility that general color error is not the best measure.

The accuracy of assessing commercialism was higher on color infrared (53 percent correct) than natural color (38 percent correct), averaged over the three scales and the interpreter groups. Identification of commercialism, itself a composite of density, height and species, was consistent with the general trend in accuracy of the two film types over all stand features. There was a distinct separation in interpretation accuracy between the film/scale combinations (Table 6). The interpretation of color infrared 1:30,000 (57 percent correct) was significantly better than natural color 1:30,000 (24 percent correct). The implication is that height, rather than species class, is the determining factor in identifying commercialism as, the color infrared 1:30,000 was less suitable for species than the natural color, but better for height. This is also evident in comparisons of accuracy of height versus commercialism for the other film/scale combinations with natural color 1:30,000.

The accuracy of identifying site was equivalent on natural color and color infrared over all scales and interpreter groups. Scale had an affect, with accuracy higher on the 1:50,000 (64 percent correct) than the 1:30,000 (47 percent correct). The synoptic view provided by smaller scales is advantageous for the interpretation of site as it is a composite characteristic, requiring the identification of species, height and relative stand position. The interaction of film and scale was also significant, illustrated by the accuracy obtained with natural color 1:50,000 (71 percent correct) compared to the same film at 1:30,000 (38 percent correct). Better site identification was attained on the larger scale color infrared 1:30,000 than the smaller scales of the same film. Neither inventory experience, nor photo-interpretation experience affected identification. Color discrimination ability did affect interpretation, with participants having higher error scores (Group 2:62 percent correct, Group 3:58 percent correct) tending to have higher accuracy scores than those with better color perception (Group 1:50 percent correct). This may have resulted from a chance selection of interpreters, the arbitrary selection of color discrimination group, or the choice of sample stands. It is also possible that site interpretation is not associated with color acuity.

Accuracy with the 1:15,000 black and white infrared was not better than any of the 6 color film/scale combinations for the identification of any forest stand characteristic.

Recreation

Observations of each characteristic were highly variable. This may be attributed to:

1. inexperience of the interpreters with the imagery
2. unfamiliarity with the interpretation specifications
3. impractical classifications for site features based on subjective estimates.

As a result, fewer conclusions were drawn with respect to film type and scales than expected.

Significantly better identification of crown type and water depth was attained on the natural color (43 and 59 percent correct respectively) than on the color infrared (34 and 50 percent correct). Neither the interpretation of water type, shoreline stability nor backshore drainage were affected by the choice of film. Interpreters found it difficult to locate small water courses obscured by forest cover. Further confusion was added due to insufficient data on the season of photography and on the amount of precipitation prior to imagery acquisition.

Scale influenced the identification accuracy of only two recreation features: topography and water type. The identification of topography tended to be better on the larger scales, with accuracies of 57, 55 and 45 percent correct for scales of 1:30,000, 1:50,000 and 1:70,000 respectively. Greater relief displacement and more vertical exaggeration at the larger scales aided the interpreters. Participants had little trouble identifying water type, with accuracy consistently high on all film/scales combinations. However, interpretation accuracy was better on the 1:50,000 (85 percent correct) than on the 1:30,000 (68 percent correct) illustrating the advantage of greater synoptic view on smaller scale imagery for tracing water courses.

When tested against the 6 color film/scale combinations, identification accuracy with 1:15,000 black and white infrared was not significantly better for any of the recreation features.

Neither inventory experience, photo-interpretation experience nor color discrimination ability affected identification accuracy of any recreation site characteristic described on any film/scale combination. Apparently, the basic training received by all participants provided sufficient information for the interpretation of the simple site classes used. As well, it appeared that color perception of the interpreter was not a limiting factor for the identification of the recreation variables examined.

Wildlife Habitat

Participants in this discipline generally had less exposure to inventory procedures and photo-interpretation (Table 8). Lower identification accuracy across most variables reflected this. Little advantage was apparent with any specific film/scale. Conventional black and white infrared did not perform significantly better than the color film/scale combinations for the identification of any habitat characteristic. Slope was discounted as accuracy was very high with all photography. Interpreters had no difficulty separating slopes of less than 30 degrees from steeper terrain. There was some confusion with the identification of vegetation species and in deciding which component occupied the dominant position. The larger scale was more suitable for estimating heights of shrub and mixed vegetation, since it was not visible on the smaller scale imagery. Interpreters were more successful with color infrared (64 percent correct) than with the natural color (50 percent correct) for the identification of site condition. In addition, interpretation accuracy tended to be higher for this characteristic on the larger scales with an identification score of 67 percent on the 1:30,000 as opposed to 50 percent and 55 percent for 1:50,000 and 1:70,000 respectively.

Field experience was not tested as a factor in this experiment due to an insufficient number of participants within the groups. The amount of photo-interpretation experience had a positive effect on the identification of site condition. Averaged over all films, scales and color discrimination groups, identification accuracy for interpreters with more than 24 months experience (69 percent correct) was significantly better than either those with less than 6 months (52 percent correct) or 6-24 months experience (53 percent correct). The interpretation of the other habitat characteristics apparently required only basic field knowledge and did not depend on familiarity with photo-interpretation. Also, color discrimination ability did not significantly affect the identification of habitat characteristics. This is not conclusive however, as all interpreters exhibited high average color perception.

Costs

A: Interpretation Time

Average interpretation times by film/scale combination are shown in Table 10. No differences were observed in times required for the interpretation of any color film/scale combination for either forestry, recreation or wildlife habitat. The decrease in spatial resolution at smaller scales did not result in the participants taking more time for interpretation. Apparently, the time required for the assembly of available visual clues for identification was not dependent on scale. Similarily, interpreters took no longer on natural color than color infrared, although the green cast, due to haze, tended to obscure ground detail on natural color imagery.

There were significant differences in time taken for identifications between the interpreter groups tested. The amount of field inventory experience did not influence the foresters but did have a negative effect on the recreation interpreters. Participants with greater experience tended

to become more involved with the appearance of the feature on the photography simply out of interest. The amount of general photo-interpretation experience influenced time taken by interpreters in all three disciplines. Forestry interpreters with greater experience tended to take less time. However, results were inconclusive: while interpreters with more than 24 months experience required significantly less time than those with 6 to 24 months experience, there was no difference between interpreters with less than 6 months experience and those with more than 24 months. This may be explained by the weighting received by only one interpreter's results in Group 2 versus 12 observations assigned to Group 1 and 4 observations to Group 3.

Times recorded for the recreation and wildlife interpreters contradict the trend toward decreased time with greater experience. Photo experience had a negative effect on interpretation time. Participants familiar with remote sensing showed more interest in the appearance of terrain features on the various film/scale combinations and generally took longer.

A significant effect of color discrimination ability on interpretation time was evident only with the wildlife biologists where significant differences were observed between the two color perception groups. Interpreters with higher error scores required more time to decide on terrain description. This was reasonable since the participant confusing colors in the discrimination test could be expected to have difficulty separating meaningful colors on the natural color and color infrared photography. Inappropriate separation into color discrimination groups and the use of total error score, rather than an evaluation of color confusion zones by individual, may account for the reverse trend shown in the other disciplines. Forestry interpreters with high error scores (70 plus) generally required more time for interpretation although not significantly more than those with the lowest error scores. Participants with moderate scores (40 to 70) took the least time, though not significantly less than those with the lowest scores. This suggests that the class limits for color discrimination were inappropriate or that total error score is an insignificant factor. All interpreters had at least normal average discrimination (Farnsworth 1957): average error scores ranged from 8 to 94. Separation of the interpreters into three classes may have been unnecessary. The range in interpretation time was only .44 minutes, which may become insignificant in an operational setting. As well, no meaningful contrasts were isolated by this separation of times. Recreation interpreters showed a greater range in error scores (125) with a shift toward higher errors. Participants with low error scores (0 to 39) took significantly longer than those with scores of 40 to 70. Interpreters having less difficulty discriminating colors might be expected to require less time to come to an interpretation decision. More research into this may be required to set proper limits on the color discrimination ability required for interpreters working with various film types.

B. Acquisition Costs

Decreased scale results in increased linespacing. Subsequently there is a reduction in number of lines and line miles, translating into less aircraft flight time. Fewer exposures are required at smaller scales with lower film, processing and reproduction costs. As an illustration of cost effectiveness, mean accuracy (average percent correct across all variables by discipline) of each film/scale combination was compared to acquisition costs (Table 9).

On a frame by frame basis, film and associated processing and reproduction costs are much higher for natural color and color infrared than black and white infrared. Although the cost of a photograph increases with altitude due to increased equipment costs and allowance for weather, the cost of block coverage decreases with higher altitudes. Scale is the most important factor in acquisition cost. There was a considerable cost reduction with decreasing scale, despite higher single exposure costs. At 1:15,000 approximately 16 times more photos were required than at a scale of 1:70,000. Increased spacing between lines resulted in fewer lines and lower linemile charges. Fewer photos require less handling time in set up and data transfer procedures.

## Conclusions

Natural color and color infrared photography at scales of 1:30,000, 1:50,000 or 1:70,000 are effective alternatives to 1:15,000 black and white infrared for the identification of the resource features tested here. Current inventory specifications consist of broad category classes for wildlife habitat, recreation sites and forest stand overstory. Experienced photo-interpreters do not require the amount of detail available on large scale photography to describe these features. The addition of color information at smaller scales compensates for reduced spatial resolution.

The overall accuracy of identifying any of the characteristics was low on all of the photography tested. In the identification of any of the resource features no advantage was evident with the use of 1:15,000 black and white infrared photography as opposed to the smaller scale natural color or color infrared imagery. Regardless of scale or the experience of the interpreters, color infrared appeared to be more suitable than natural color for the interpretation of commercialism (forestry) and wildlife habitat site condition. Natural color was better for the identification of crown type and water depth on the recreation sites. Neither interpretation accuracy of the other resource characteristics, nor interpretation time were affected by the choice of film.

The selection of scale affected the interpretation of stand density, species composition, site index, topography, water

type and habitat site condition. With the exception of topography and site condition, no advantage was demonstrated in choosing a larger scale than 1:50,000 for the identification of the other resource characteristics. The time required for photo-interpretation by any set of interpreters was not influenced by the choice of scale.

Interpreter inventory experience affected only the identification of species composition (forestry) and interpretation time required (recreation). In each case, increased experience resulted in better performance on the small scale color imagery. The level of experience did not affect interpretation accuracy of the other resource characteristics nor time required by forestry or wildlife interpreters.

Increased photo-interpretation experience resulted in better species identification in forest stands, and a more accurate estimate of wildlife habitat site condition. The identification accuracy of other resource characteristics was not influenced by this factor. Photo experience had a positive effect on identification time required by the forestry photo-interpreters but did not result in reduced times for the recreation or wildlife interpreters.

Interpreter color discrimination ability had a positive influence on the accuracy of identifying tree species composition. Color perception had an inconsistent effect on the identification of site index and the times required by all interpreters. It did not influence the accuracy of identification of other resource characteristics.

The analysis of acquisition costs for the small scale color imagery indicated that on a frame by frame basis, the cost of black and white infrared is appreciably less than either of the color films. This remains constant. However, with smaller scale color imagery, areal coverage is more extensive on each photo reducing the number of frames required for stereoscopic coverage, and therefore the cost. As a result, total cost of imagery acquisition is reduced for smaller scales without a sacrifice of identification accuracy.

## Recommendations

Color infrared 1:50,000 is recommended as a imagery base for multiresource inventories.

Overstory vegetation types are easily identified by inexperienced photo-interpreters on this imagery and the large synoptic view at this scale is helpful for feature identification and management planning in forestry (recognition of fire boundaries), recreation (location and access), and wildlife (habitat dispersal).

Further research is suggested to address the following questions:

1. Is black and white infrared at scales of 1:30,000, 1:50,000 or 1:70,000 suitable for the identification of resource characteristics and qualities?
2. What are the ramifications of using small scale photography on the specifications for minimum size area delineation, vegetation description, and data transfer to base maps?
3. Can color prints serve as a cost effective alternative to transparencies for photo-interpretation?
4. What are the effects of interpreter knowledge of the terrain in a specific area, variable optical magnification, interpretation experience with the selected imagery types and scales, and interpreter age on the accuracy of identifying resource characteristics?
5. In forest stands, can understory and minor species be identified accurately on small scale natural color or color infrared photography?
6. What is the effect of interpreter color confusion, within specific color regions, on the accuracy of feature identification?

Regardless of the imagery selected, additional questions related to management implications arise as a result of this study, in particular:

1. What level of identification accuracy and consistency is required by land managers? Can photo interpretation achieve this accuracy?
2. What are the associated costs in equipment and manpower requirements for the implementation of a small scale color photography interpretation system?

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Figure 2. Color infrared 1:54,000 of Area 2, Cache Percotte Forest. Forest stand descriptions are prefixed by "F", recreation sites by "R". Refer to Tables 1-3 for specifications.

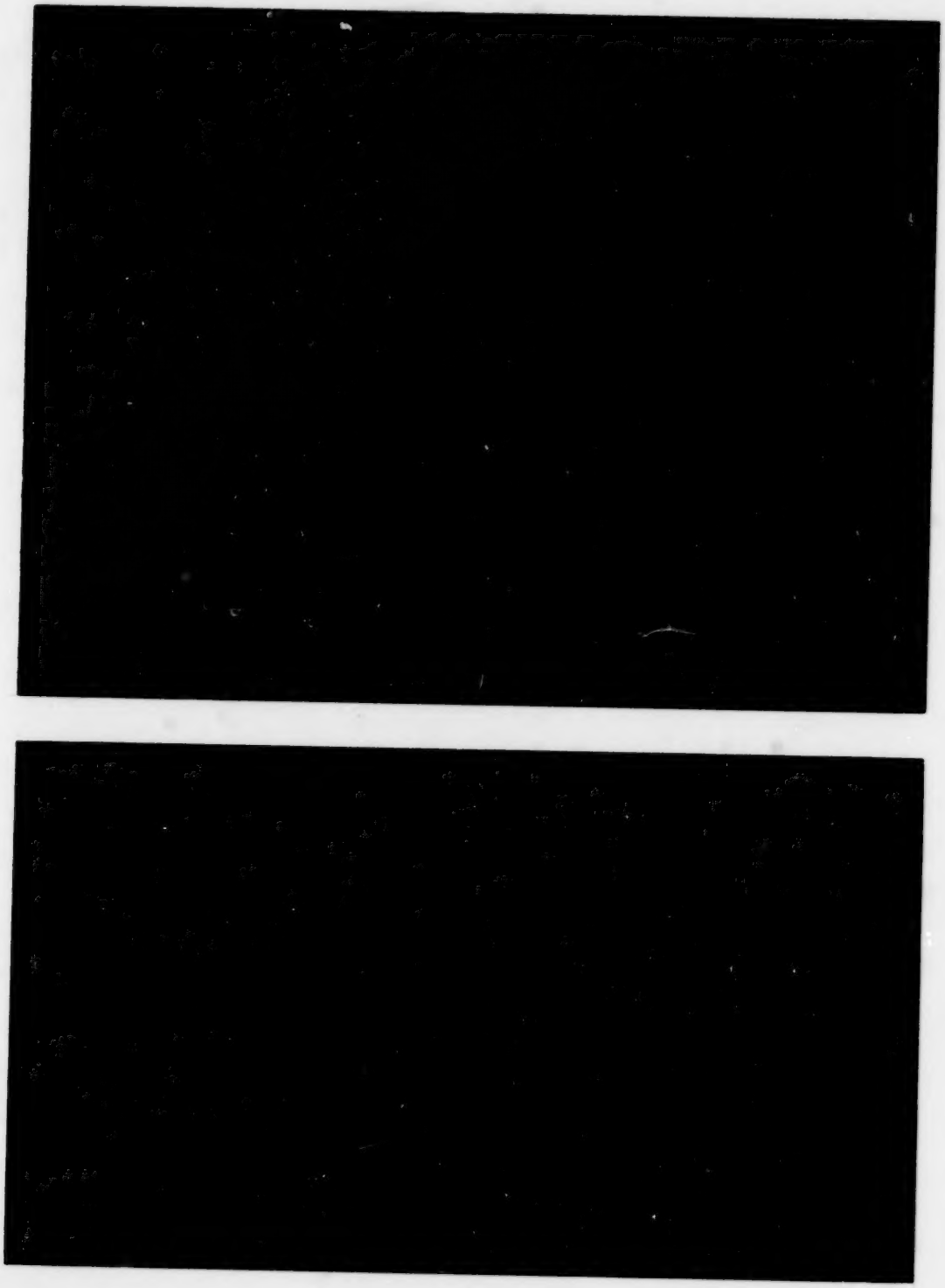

Figure 3. Top: Color infrared 1:29,400 of Area 1, Two Creek.
Bottom: Natural color 1:67,500 of Area 1, Two Creek.

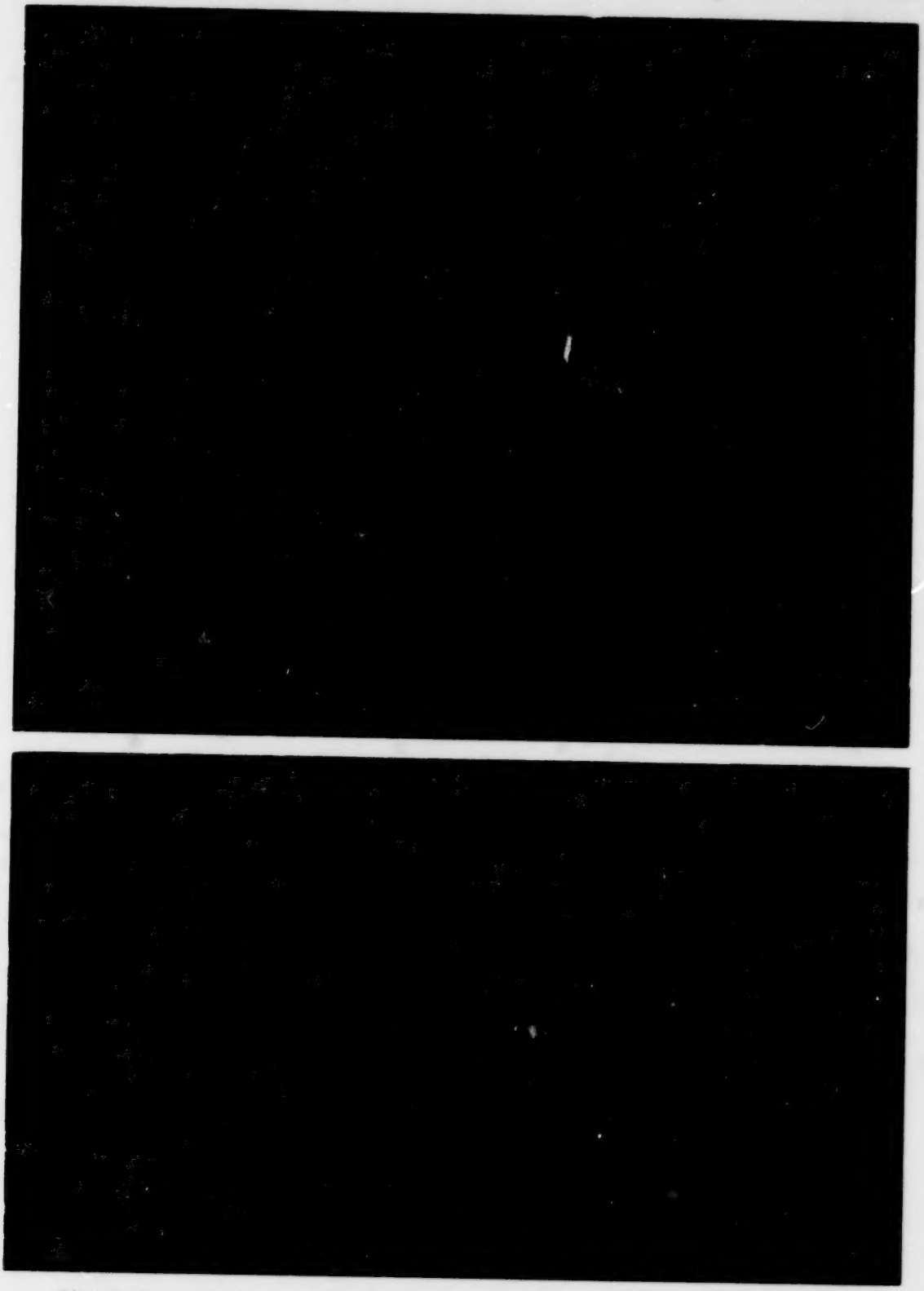

Figure 4. Top: Natural color 1:26,800 of Area 3, Wildhay River.
Bottom: Color infrared 1:64,900 of Area 3, Wildhay River.

Table 1: Forestry Interpretation Specifications

| Variable | Class | Description |
|---|---|---|
| Density | A | 6-30% crown density |
| | B | 31-50% |
| | C | 51-70% |
| | D | 71-100% |
| Height | 0 | 0.0- 6.0 metres |
| | 1 | 6.1-12.0 |
| | 2 | 12.1-18.0 |
| | 3 | 18.1-24.0 |
| | 4 | 24.1-30.0 |
| | 5 | 30.1 and over |
| Species | CP | Conifer with pine dominant |
| | CSw | Conifer with White spruce dominant |
| | CSb | Conifer with Black spruce dominant |
| | H | Aspen or other deciduous |
| | MP | Mixedwood with pine dominant |
| | MSw | Mixedwood with White spruce dominant |
| | MSb | Mixedwood with Black spruce dominant |
| | MA | Mixedwood with deciduous dominant |
| Commercialism | L | Lumber: Minimum 50 cubic metres per hectare gross coniferous sawlog unless 40% plus merchantable stem are of roundwood size. |
| | R | Roundwood: 50 cubic metres per hectare gross coniferous |
| | H | High Uncommercial: 50 cubic metres per hectare gross all species |
| | U | Low Uncommercial: less than 50 cubic metres per hectare gross all species |
| Site (70 years) | G | Good: 20 plus metres White spruce, Pine and aspen; 12 plus metres Black spruce |
| | M | Medium: 15-20 metres White spruce, Pine, Aspen: 9-12 metres Black spruce. |
| | F | Fair: less than 15 metres and 9 metres respectively. |

Table 2: Wildlife Habitat Interpretation Specifications

| Variable | Class | Description |
|---|---|---|
| Habitat Type | 01 | Grass meadow: 70 percent plus grass |
| | 02 | Mixed meadow: 50 percent plus grass |
| | 03 | Mixed meadow: 50 percent plus shrub |
| | 04 | Shrub meadow: 70 percent plus shrub |
| | 05 | Sedge meadow |
| | 06 | Open muskeg |
| | 07 | Treed muskeg |
| | 08 | Deciduous: 70 percent plus deciduous |
| | 09 | Mixed wood: 50 percent plus deciduous |
| | 10 | Mixed wood: 50 percent plus coniferous |
| | 11 | Coniferous: 70 percent plus coniferous |
| Species | W | Willow |
| | B | Dwarf Birch |
| | O | Other shrub |
| | Sw | White spruce |
| | Sb | Black spruce |
| | P | Lodgepole pine |
| | Fb | Balsam and alpine fir |
| | Fd | Douglas fir |
| | Lt | Larch |
| | A | Deciduous |
| Height | 0 | 0.0 to 0.3 metres (grass) |
| | 1 | 0.3 to 2.0 metres |
| | 2 | 2.1 to 6.0 metres |
| | 3 | 6.1 plus metres |
| Slope | 1 | Less than 30 degrees (57.7 percent) |
| | 2 | Greater than 30 degrees |
| Aspect | 1 | West, southwest, south |
| | 2 | Bottomland |
| | 3 | Other slope |
| Site Condition | 0 | Improved |
| | 1 | Overused |
| | 2 | Wet |
| | 3 | Dry |
| | 4 | Cutover |
| | 5 | Disturbed |

Table 3: Recreation Site Interpretation Specifications

| Variable | Class | Description |
|---|---|---|
| Topography | 1 | Flat |
| | 2 | Gently rolling |
| | 3 | Hilly |
| | 4 | Rugged |
| Crown Type | 1 | Deciduous |
| | 2 | Coniferous |
| | 3 | Mixed deciduous minimum 25 percent coniferous. |
| | 4 | Mixed coniferous with minimum 25 percent deciduous. |
| | 5 | No crown cover |
| Water Type | 1 | Lake |
| | 2 | Reservoir |
| | 3 | Pond/slough |
| | 4 | Wetland |
| | 5 | Stream/river |
| | 6 | Spring |
| Water Depth | 1 | Standing: less than 2 metres |
| | 2 | Standing: more than 2 metres |
| | 3 | Flowing: Shallow: 0.0 to 0.3 metres |
| | 4 | Flowing: Low: 0.3 to 1.0 metres |
| | 5 | Flowing: Deep: more than 1.0 metres |
| Shoreline Stability | 1 | Stable |
| | 2 | Unstable |
| | 3 | Active |
| Backshore Drainage | 1 | Well |
| | 2 | Moderate |
| | 3 | Poor |
| Attractiveness | 1-10 | Low to high estimate |
| Capability for Camping | 1-10 | Low to high estimate |

Table 4: Average Photo Scales Acquired by Film and Area

| Film Type | Area 1 | Area 2 | Area 3 |
|---|---|---|---|
| Natural Color and Color Infrared | 1:29,400 | 1:27,800 | 1:26,800 |
| Natural Color and Color Infrared | 1:54,560 | 1:54,000 | 1:52,100 |
| Natural Color and Color Infrared | 1:67,500 | 1:65,600 | 1:64,900 |
| Black and White Infrared | 1:15,000 | 1:15,000 | 1:21,000 |

Table 5: Number of Interpreters Assigned to Experimental Groups

| Factor | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Experience | 0-6 months | 2-24 months | 24 plus months |
| A. Inventory | | | |
| Forestry | 4 | 6 | 7 |
| Recreation | 3 | 3 | 6 |
| Wildlife | - | - | - |
| B. Photo-interpretation | | | |
| Forestry | 12 | 1 | 4 |
| Recreation | 4 | 4 | 4 |
| Wildlife | 4 | 1 | 2 |
| C. Color Discrimination | | | |
| | Good 0-39 | Medium 40-68 | Poor 69 plus |
| Forestry | 7 | 5 | 5 |
| Recreation | 4 | 5 | 3 |
| Wildlife | 4 | 3 | - |

Table 6: Analyses of Variance for Natural Color and Color Infrared Photography

| VARIABLE | FACTORS A | B | C | D1 | D2 | D3 | BC |
|---|---|---|---|---|---|---|---|
| FORESTRY | | | | | | | |
| Density | | | * | | | | |
| Height | * | | | | | | |
| Species Class | * | | * | * | * | * | * |
| Commercialism | * | * | | | | | * |
| Site | | | * | | | | * |
| Time | | | | | | * | * |
| | | | | | * | * | |
| RECREATION | | | | | | | |
| Topography | | | * | | | | |
| Crown Type | | * | | | | | * |
| Water Type | * | | * | | | | |
| Water Depth | * | * | | | | | |
| Shoreline Stability | * | | | | | | * |
| Backshore Drainage | | | | | | | * |
| Attractiveness | | | | | | | * |
| Capability for Camping | | | | | | | |
| Time | | | | * | * | * | |
| WILDLIFE HABITAT | | | | | | | |
| Habitat Type | | | | | | | |
| Species | * | | | | | | |
| Height | | | | | | | |
| Slope | | | | | | | |
| Aspect | * | | | | | | |
| Site Condition | * | * | * | | * | | * |
| Time | * | | | | * | * | |

FACTORS : A: Blocks (3)
B: Film Types (2)
C: Scales (3)
D1: Interpreter Field Experience (3 Groups)
D2: Interpreter Photo-Interpretation Experience (3 Groups)
D3: Interpreter Color Discrimination Test Score (3 Groups)

NOTE: Significant Level = .95
* Indicates Significant Variance Ratio

Table 7: Accuracy Scores By Film/Scale Combination in Percent

| FILM TYPE | NATURAL COLOR | | | COLOR INFRARED | | | B & W IR |
|---|---|---|---|---|---|---|---|
| SCALE | 1:30,000 | 1:50,000 | 1:70,000 | 1:30,000 | 1:50,000 | 1:70,000 | 1:15,000 |
| FORESTRY | | | | | | | |
| Density | 56 | 58 | 74 | 67 | 60 | 72 | 79 |
| Height | 28 | 61 | 54 | 66 | 41 | 58 | 52 |
| Species Class | 57 | 42 | 48 | 37 | 65 | 32 | 47 |
| Commercialism | 24 | 39 | 49 | 57 | 54 | 49 | 47 |
| Site | 38 | 71 | 50 | 56 | 57 | 64 | 28 |
| RECREATION | | | | | | | |
| Topography | 68 | 50 | 40 | 46 | 60 | 50 | 42 |
| Crown Type | 35 | 49 | 44 | 40 | 25 | 36 | 33 |
| Water Type | 68 | 82 | 82 | 68 | 89 | 76 | 81 |
| Water Depth | 58 | 68 | 51 | 54 | 42 | 56 | 42 |
| Stability | 29 | 53 | 47 | 56 | 54 | 38 | 44 |
| Drainage | 47 | 53 | 53 | 56 | 35 | 58 | 61 |
| Attractiveness | 14 | 19 | 17 | 19 | 19 | 21 | 14 |
| Cap. Camping | 25 | 17 | 13 | 13 | 17 | 22 | 15 |
| WILDLIFE HABITAT | | | | | | | |
| Habitat Type | 24 | 19 | 29 | 26 | 33 | 31 | 19 |
| Species | 33 | 26 | 33 | 36 | 43 | 38 | 36 |
| Height | 43 | 50 | 48 | 45 | 52 | 38 | 66 |
| Slope | 86 | 95 | 86 | 83 | 88 | 98 | 100 |
| Aspect | 57 | 67 | 36 | 52 | 38 | 62 | 55 |
| Site Condition | 62 | 41 | 48 | 71 | 60 | 62 | 40 |

Source: Forestry: 102 observations
Recreation: 72 observations
Wildlife Habitat: 42 observations

TABLE 8: Summary of Interpreter Questionnaires

| A. INTERPRETER EXPERIENCE WITH: | FORESTRY | | | RECREATION | | | WILDLIFE | | |
|---|---|---|---|---|---|---|---|---|---|
| | EXTENSIVE | MODERATE | LITTLE | EXTENSIVE | MODERATE | LITTLE | EXTENSIVE | MODERATE | LITTLE |
| 1. Black & White Infrared 1:15,000 | 5 | 10 | 2 | 2 | 8 | 2 | 1 | 2 | 4 |
| 2. Natural Color | 1 | 4 | 12 | 0 | 6 | 6 | 0 | 0 | 7 |
| 3. Color Infrared | 0 | 1 | 16 | 0 | 6 | 6 | 0 | 1 | 6 |
| 4. Small Scale Photography | 2 | 5 | 10 | 4 | 6 | 2 | 1 | 2 | 4 |
| 5. Interpretscope | 0 | 1 | 16 | 0 | 3 | 9 | 0 | 0 | 7 |

B. INTERPRETER FILM/SCALE PREFERENCE

| | NATURAL COLOR | | | COLOR INFRARED | | | BLACK AND WHITE INFRARED | |
|---|---|---|---|---|---|---|---|---|
| | 1:30,000 | 1:50,000 | 1:70,000 | 1:30,000 | 1:50,000 | 1:70,000 | 1:15,000 | NO PREFERENCE |
| **FORESTRY** | | | | | | | | |
| DENSITY | 2 | 0 | 2 | 8 | 1 | 1 | 3 | 0 |
| HEIGHT | 2 | 0 | 1 | 1 | 0 | 0 | 13 | 0 |
| SPECIES | 0 | 0 | 0 | 12 | 2 | 0 | 3 | 0 |
| COMMERCIALISM | 0 | 0 | 0 | 3 | 1 | 0 | 11 | 2 |
| SITE | 3 | 0 | 0 | 6 | 1 | 2 | 4 | 1 |
| **RECREATION** | | | | | | | | |
| TOPOGRAPHY | 0 | 0 | 0 | 6 | 3 | 1 | 2 | 0 |
| CROWN COVER | 0 | 0 | 0 | 8 | 1 | 0 | 3 | 0 |
| WATER TYPE | 0 | 1 | 0 | 8 | 0 | 0 | 3 | 0 |
| WATER DEPTH | 1 | 0 | 0 | 9 | 0 | 0 | 2 | 0 |
| STABILITY | 0 | 1 | 0 | 5 | 1 | 0 | 4 | 1 |
| DRAINAGE | 0 | 1 | 0 | 9 | 1 | 0 | 1 | 0 |
| ATTRACTIVENESS | 2 | 1 | 2 | 5 | 0 | 1 | 1 | 0 |
| CAP. CAMPING | 2 | 0 | 1 | 4 | 1 | 0 | 4 | 0 |
| **WILDLIFE HABITAT** | | | | | | | | |
| HABITAT TYPE | 0 | 1 | 0 | 1 | 5 | 0 | 0 | 0 |
| SPECIES | 1 | 0 | 0 | 4 | 2 | 0 | 0 | 0 |
| HEIGHT | 0 | 1 | 0 | 2 | 1 | 0 | 3 | 0 |
| SLOPE | 1 | 0 | 1 | 0 | 3 | 1 | 1 | 0 |
| ASPECT | 1 | 0 | 0 | 0 | 3 | 2 | 1 | 0 |
| SITE | 0 | 1 | 0 | 2 | 3 | 0 | 1 | 0 |

TABLE 9: Overall Film/Scale Accuracy and Imagery Acquisition Costs

| FILM TYPE | NATURAL COLOR | | | COLOR INFRARED | | | B & W IR |
|---|---|---|---|---|---|---|---|
| SCALE | 1:30,000 | 1:50,000 | 1:70,000 | 1:30,000 | 1:50,000 | 1:70,000 | 1:15,000 |
| FORESTRY | 45 | 57 | 59 | 65 | 59 | 60 | 53 |
| RECREATION | 51 | 59 | 53 | 53 | 51 | 52 | 50 |
| WILDLIFE | 51 | 50 | 46 | 52 | 52 | 55 | 53 |
| COST($/SQ.KM) | 3.5 | 1.8 | 1.3 | 3.9 | 1.9 | 1.3 | 5.8 |

SOURCE: FORESTRY: Accuracy calculated with primary species recognition
RECREATION: Accuracy calculated excluding estimates of attractiveness and capability for camping
WILDLIFE HABITAT: Accuracy calculated with all variables

TABLE 10: Mean Time (Minutes) Recorded for the Interpretation of Two Sample Sites Per Stereo Pair by Film/Scale Combination

| FILM TYPE | NATURAL COLOR | | | COLOR INFRARED | | |
|---|---|---|---|---|---|---|
| SCALE | 1:30,000 | 1:50,000 | 1:70,000 | 1:30,000 | 1:50,000 | 1:70,000 |
| FORESTRY | 1.9 | 2.0 | 1.7 | 1.6 | 1.6 | 1.8 |
| RECREATION | 3.3 | 3.4 | 3.0 | 3.2 | 3.1 | 3.5 |
| WILDLIFE | 3.6 | 3.3 | 3.6 | 3.6 | 2.9 | 3.1 |

SOURCE: Forestry: 102 Observations
Recreation: 72 Observations
Wildlife Habitat: 42 Observations